Fig. 1

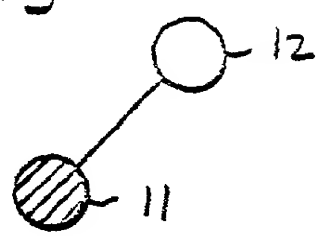


Fig. 2

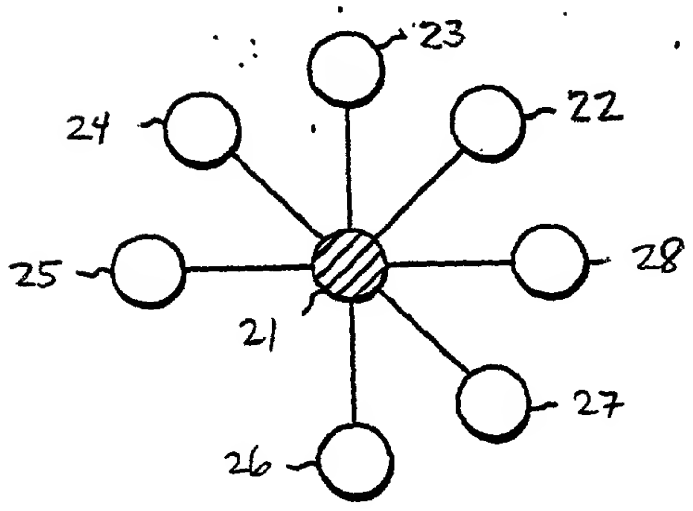
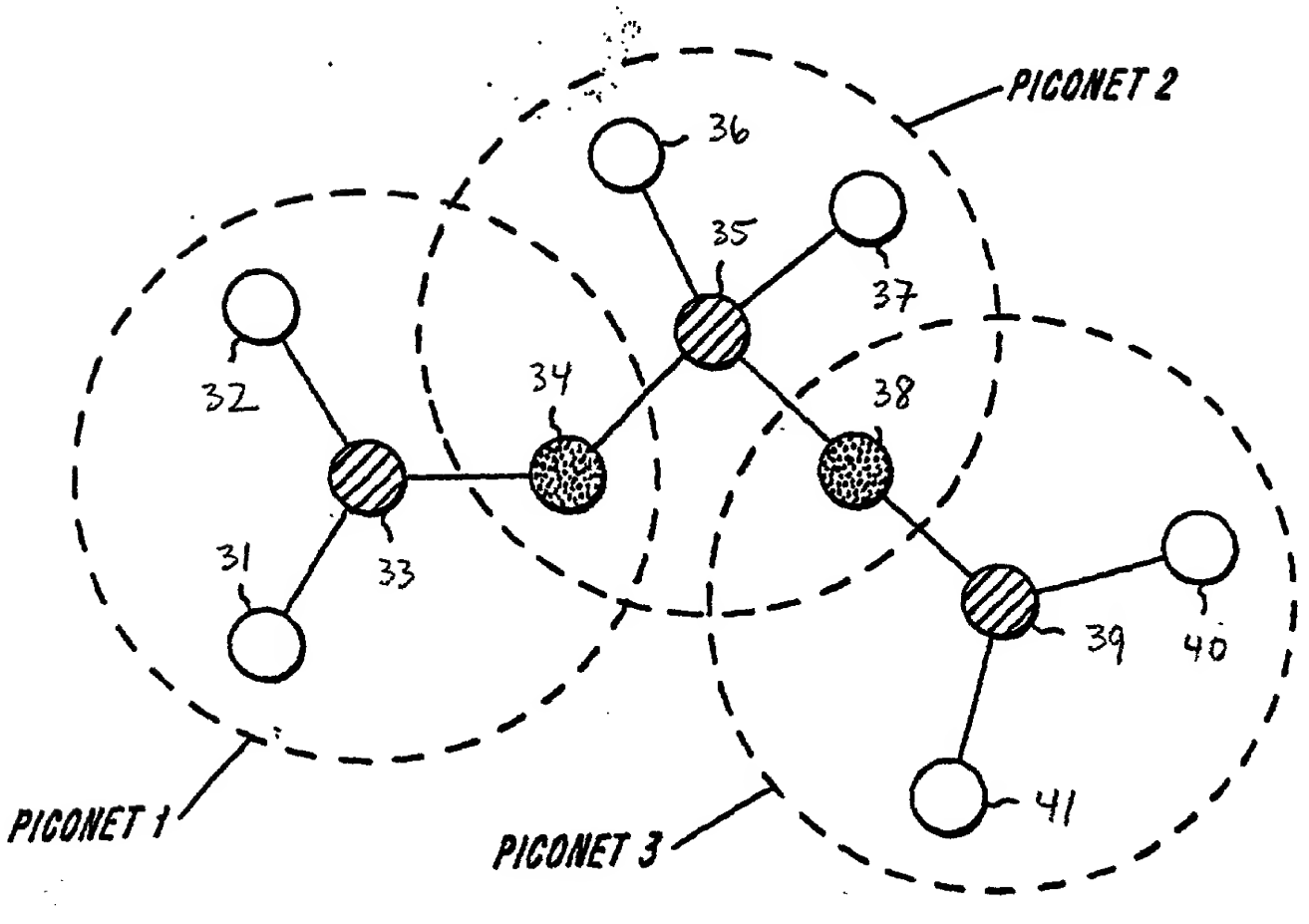


Fig. 3



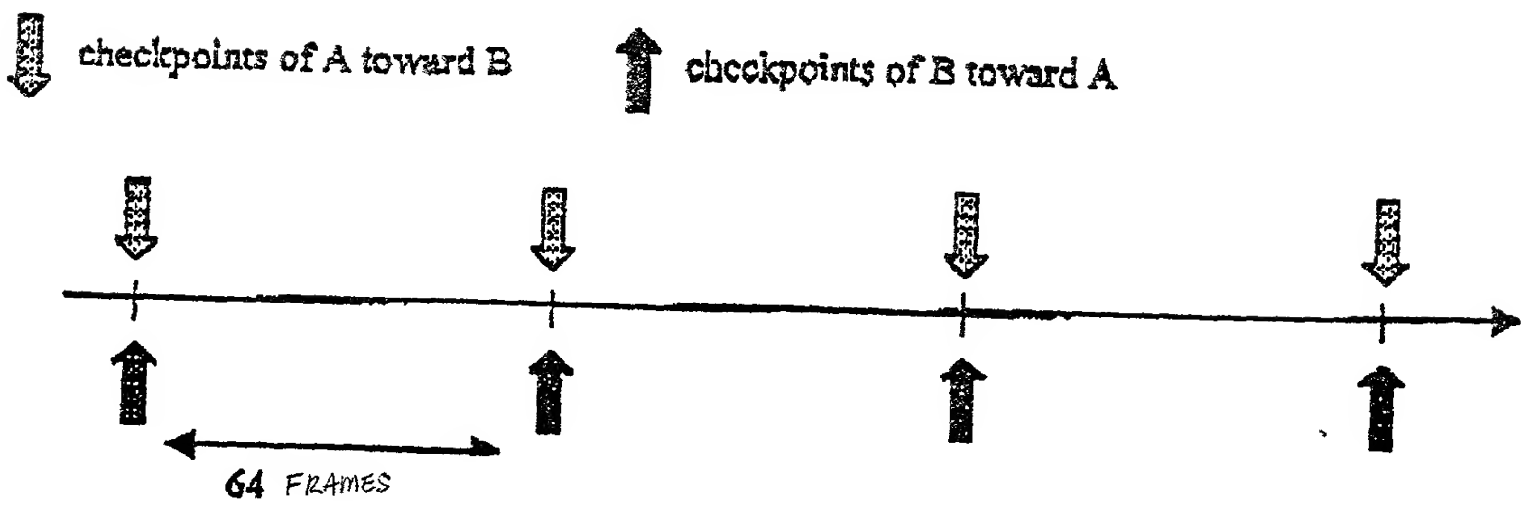

checkpoints of A toward B
checkpoints of B toward A
64 FRAMES

FIG. 4(a)

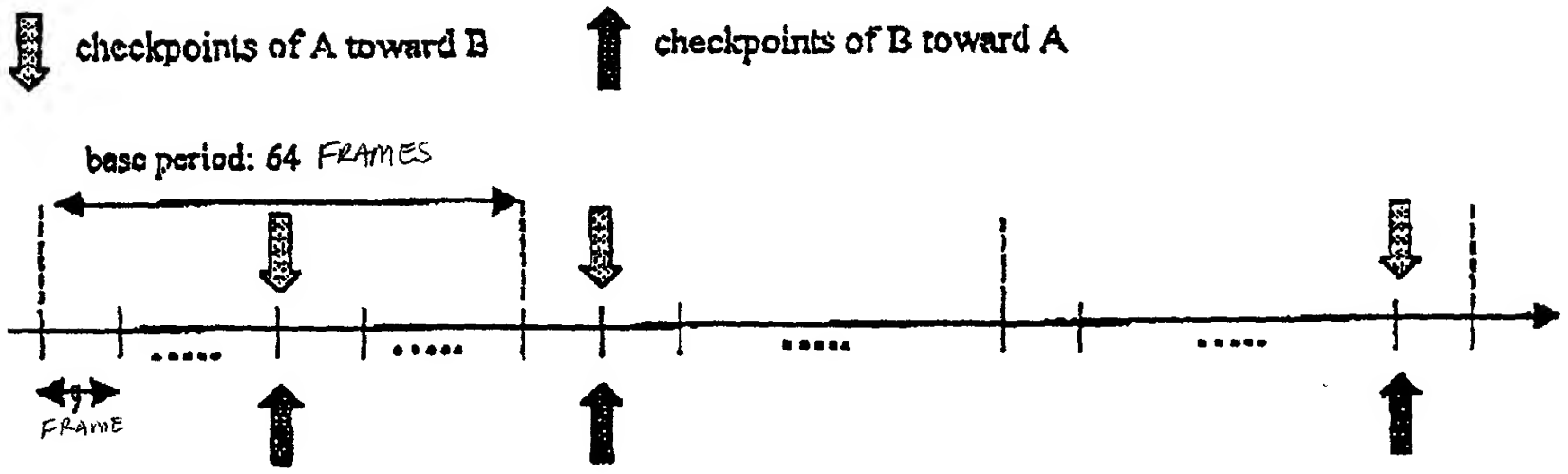

checkpoints of A toward B
checkpoints of B toward A
base period: 64 FRAMES
g FRAME

FIG. 4(b)

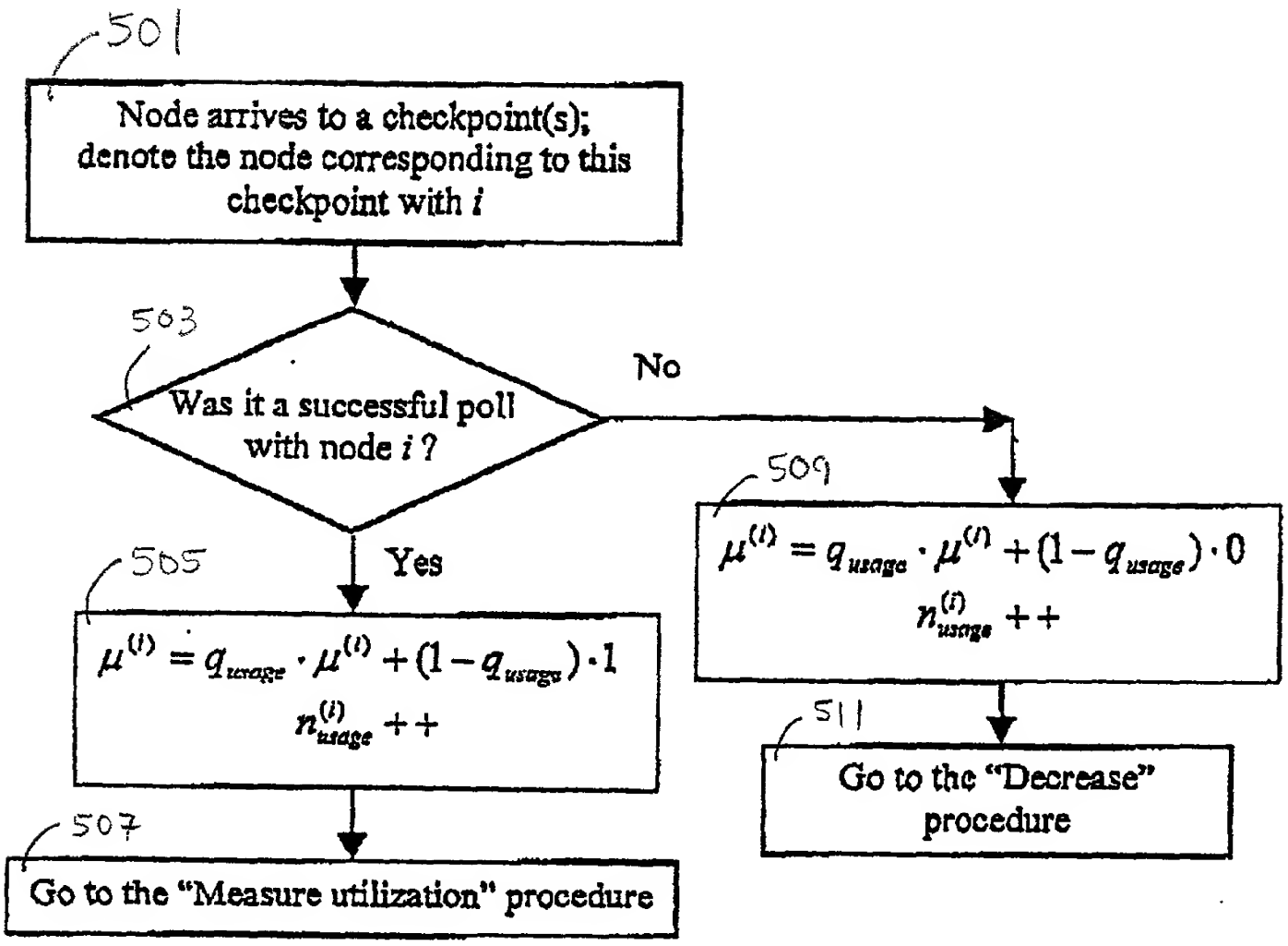

501
Node arrives to a checkpoint(s); denote the node corresponding to this checkpoint with *i*
503
Was it a successful poll with node *i* ?
No
Yes
509
$\mu^{(i)} = q_{usage} \cdot \mu^{(i)} + (1 - q_{usage}) \cdot 0$
$n_{usage}^{(i)} ++$
505
$\mu^{(i)} = q_{usage} \cdot \mu^{(i)} + (1 - q_{usage}) \cdot 1$
$n_{usage}^{(i)} ++$
511
Go to the "Decrease" procedure
507
Go to the "Measure utilization" procedure

FIG. 5

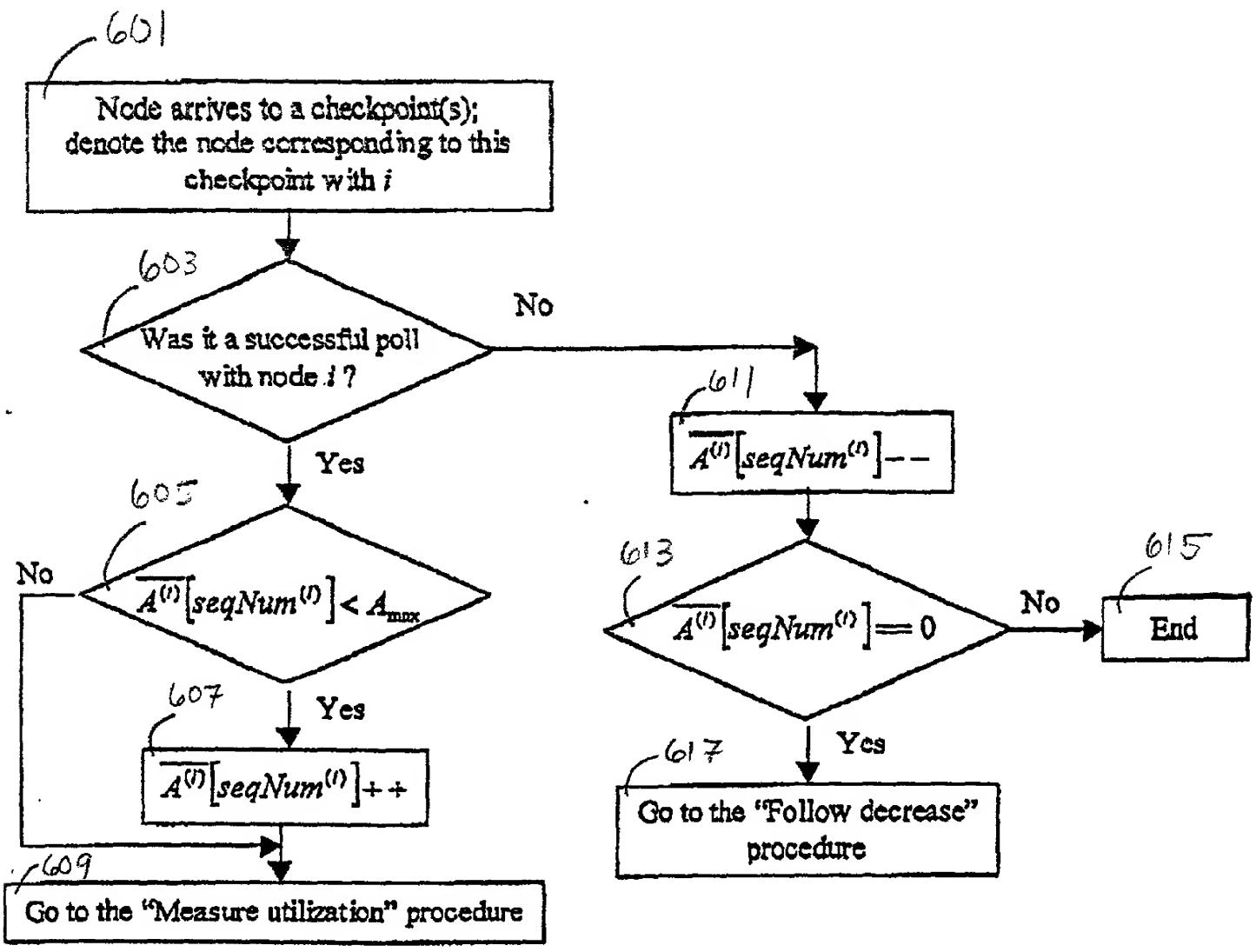

601
Node arrives to a checkpoint(s); denote the node corresponding to this checkpoint with i
603
Was it a successful poll with node i ?
No
Yes
611
$\overline{A^{(i)}}[seqNum^{(i)}]--$
605
No
$\overline{A^{(i)}}[seqNum^{(i)}] < A_{max}$
607
Yes
$\overline{A^{(i)}}[seqNum^{(i)}]++$
609
Go to the "Measure utilization" procedure
613
$\overline{A^{(i)}}[seqNum^{(i)}] == 0$
No
615
End
Yes
617
Go to the "Follow decrease" procedure

FIG. 6

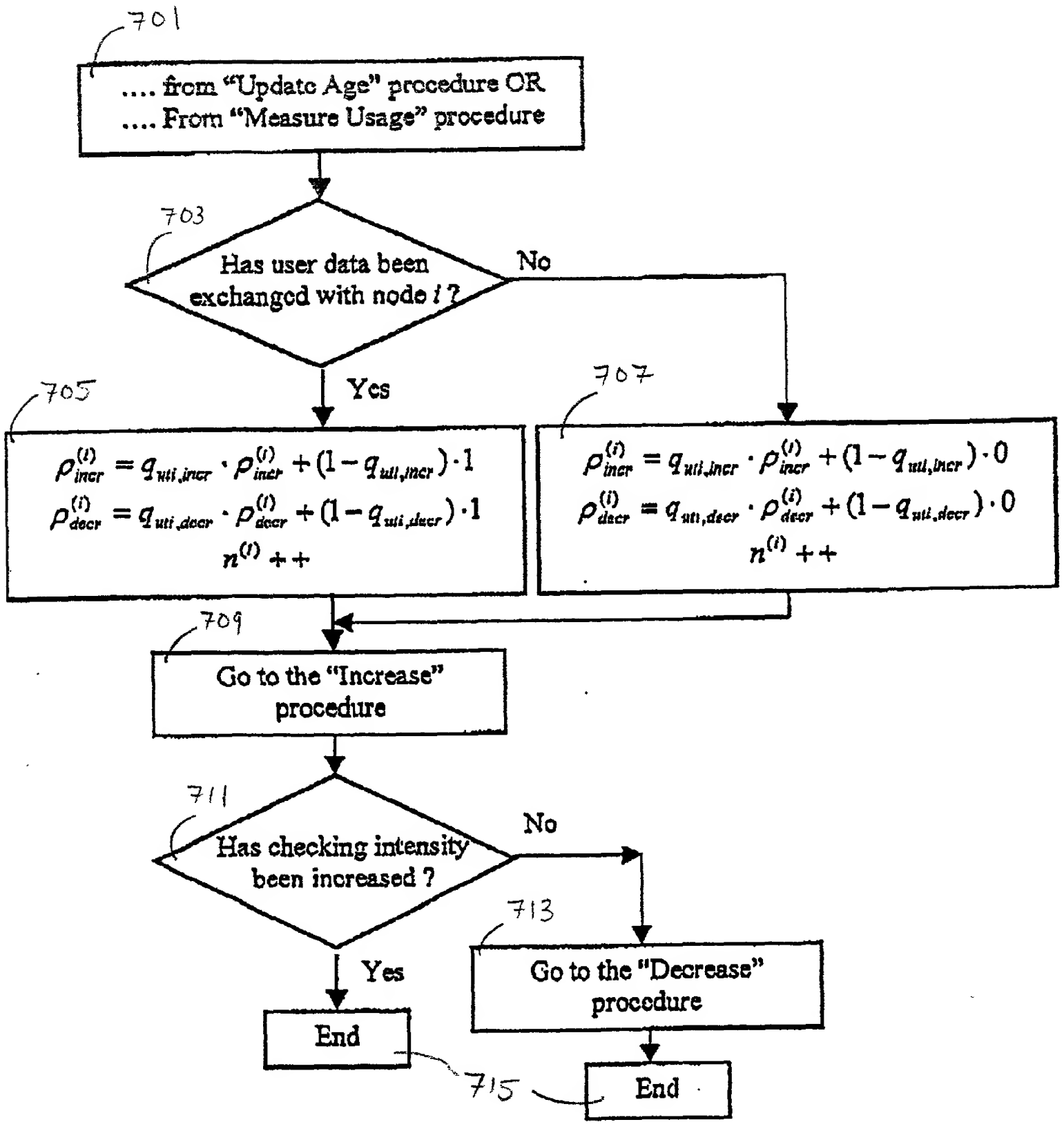
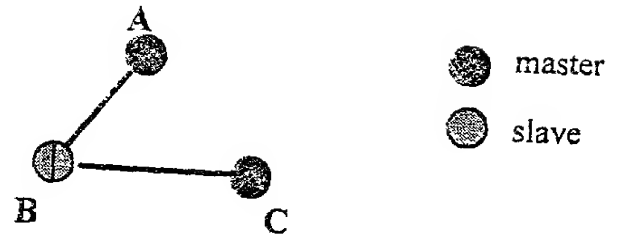

701
.... from "Update Age" procedure OR
.... From "Measure Usage" procedure
703
Has user data been exchanged with node i ?
No
Yes
705
$\rho_{incr}^{(i)} = q_{uti,incr} \cdot \rho_{incr}^{(i)} + (1 - q_{uti,incr}) \cdot 1$
$\rho_{decr}^{(i)} = q_{uti,decr} \cdot \rho_{decr}^{(i)} + (1 - q_{uti,decr}) \cdot 1$
$n^{(i)}$ ++
707
$\rho_{incr}^{(i)} = q_{uti,incr} \cdot \rho_{incr}^{(i)} + (1 - q_{uti,incr}) \cdot 0$
$\rho_{decr}^{(i)} = q_{uti,decr} \cdot \rho_{decr}^{(i)} + (1 - q_{uti,decr}) \cdot 0$
$n^{(i)}$ ++
709
Go to the "Increase" procedure
711
Has checking intensity been increased ?
No
Yes
713
Go to the "Decrease" procedure
End
715
End

FIG. 7

FIG. 8(a)



Example network

FIG. 8(b)

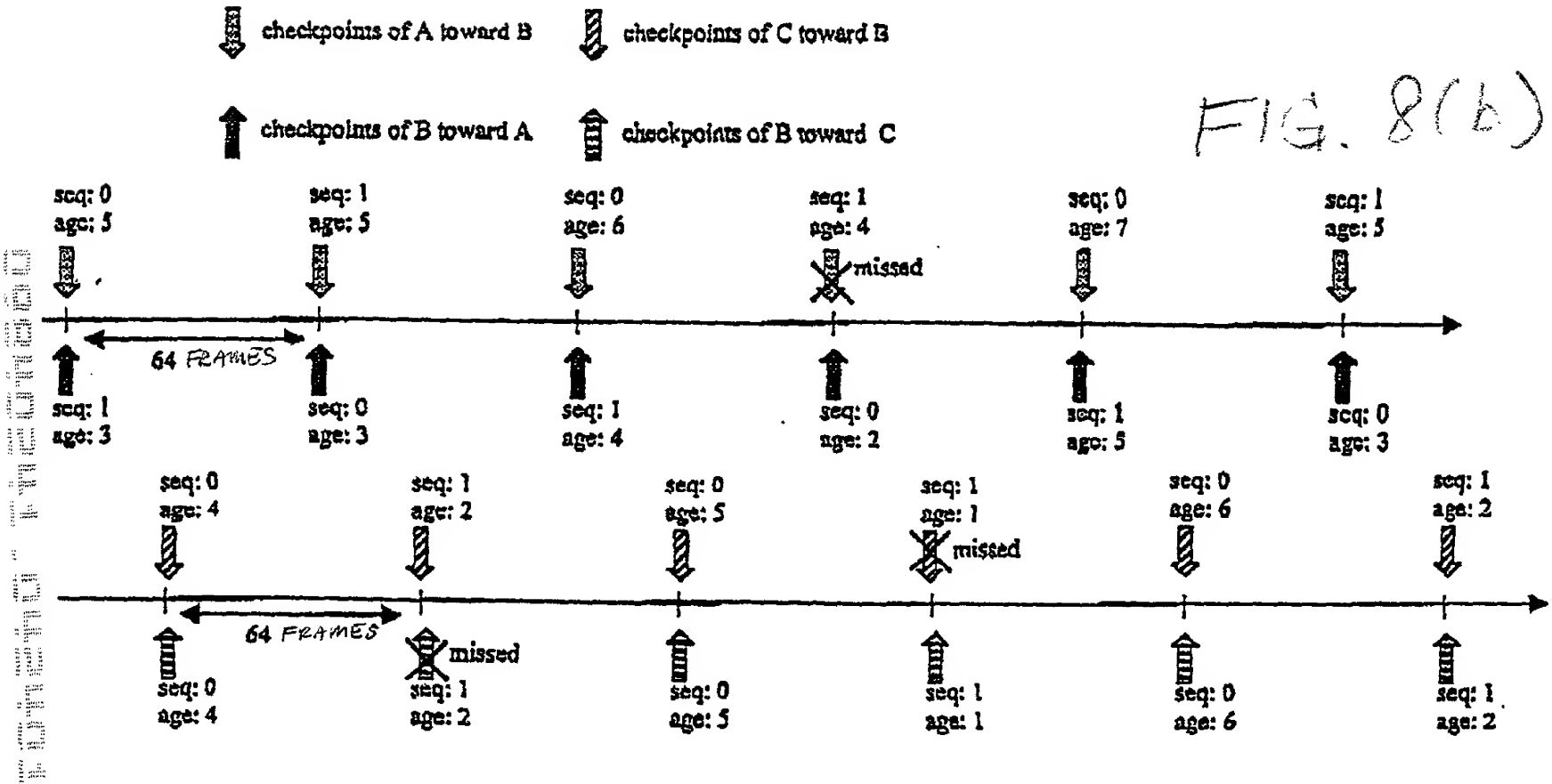


FIG. 8(c)

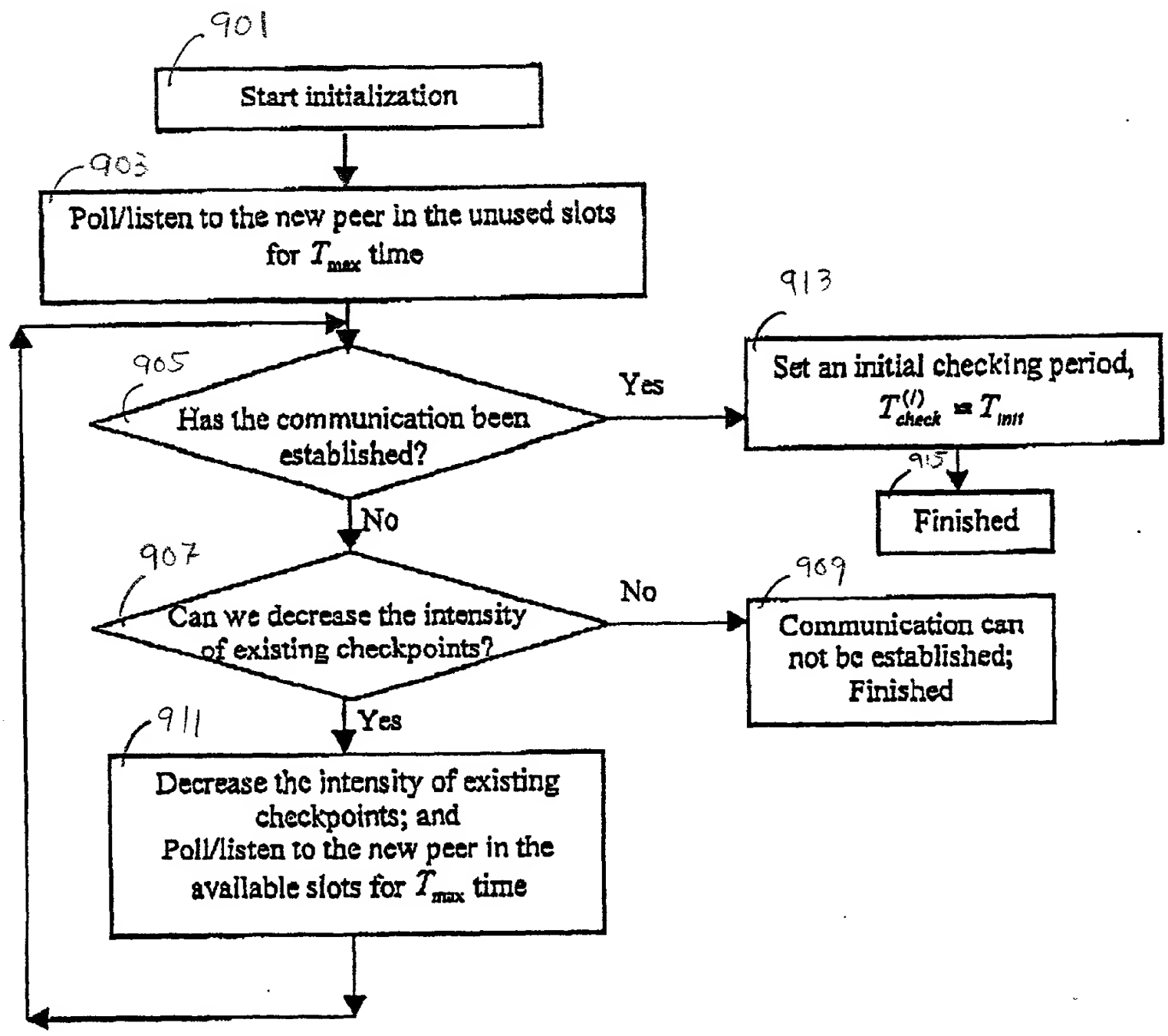

901
Start initialization
903
Poll/listen to the new peer in the unused slots for T_{max} time
905
Has the communication been established?
Yes
913
Set an initial checking period, $T_{check}^{(l)} = T_{init}$
915
Finished
No
907
Can we decrease the intensity of existing checkpoints?
No
909
Communication can not be established; Finished
Yes
911
Decrease the intensity of existing checkpoints; and
Poll/listen to the new peer in the available slots for T_{max} time

FIG. 9

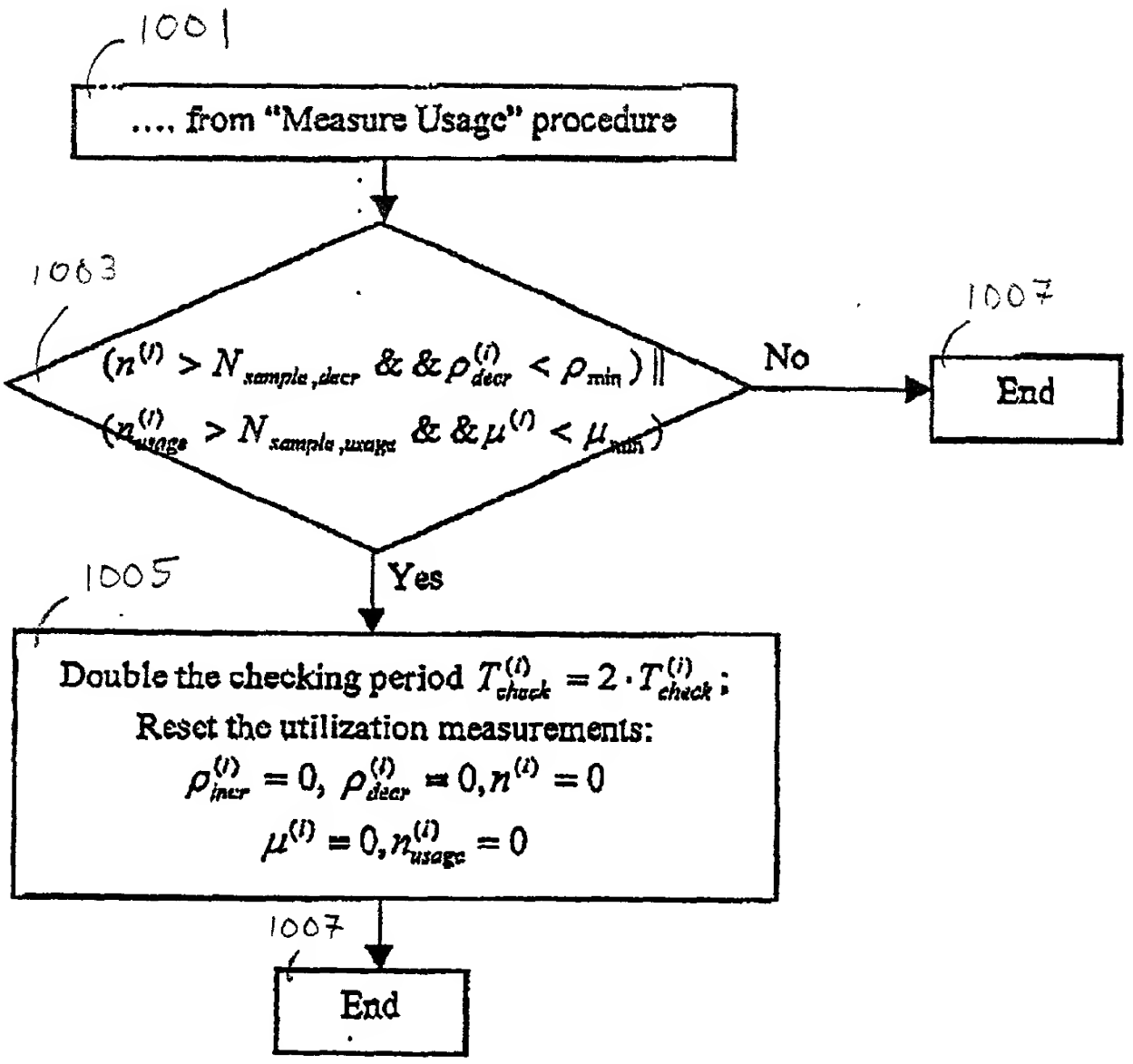

1001
.... from "Measure Usage" procedure
1003
$(n^{(i)} > N_{sample,decr} \&\& \rho_{decr}^{(i)} < \rho_{min}) \|$
$(n_{usage}^{(i)} > N_{sample,usage} \&\& \mu^{(i)} < \mu_{min})$
No
1007
End
Yes
1005
Double the checking period $T_{check}^{(i)} = 2 \cdot T_{check}^{(i)}$;
Reset the utilization measurements:
$\rho_{incr}^{(i)} = 0,\ \rho_{decr}^{(i)} = 0, n^{(i)} = 0$
$\mu^{(i)} = 0, n_{usage}^{(i)} = 0$
1007
End

FIG. 10

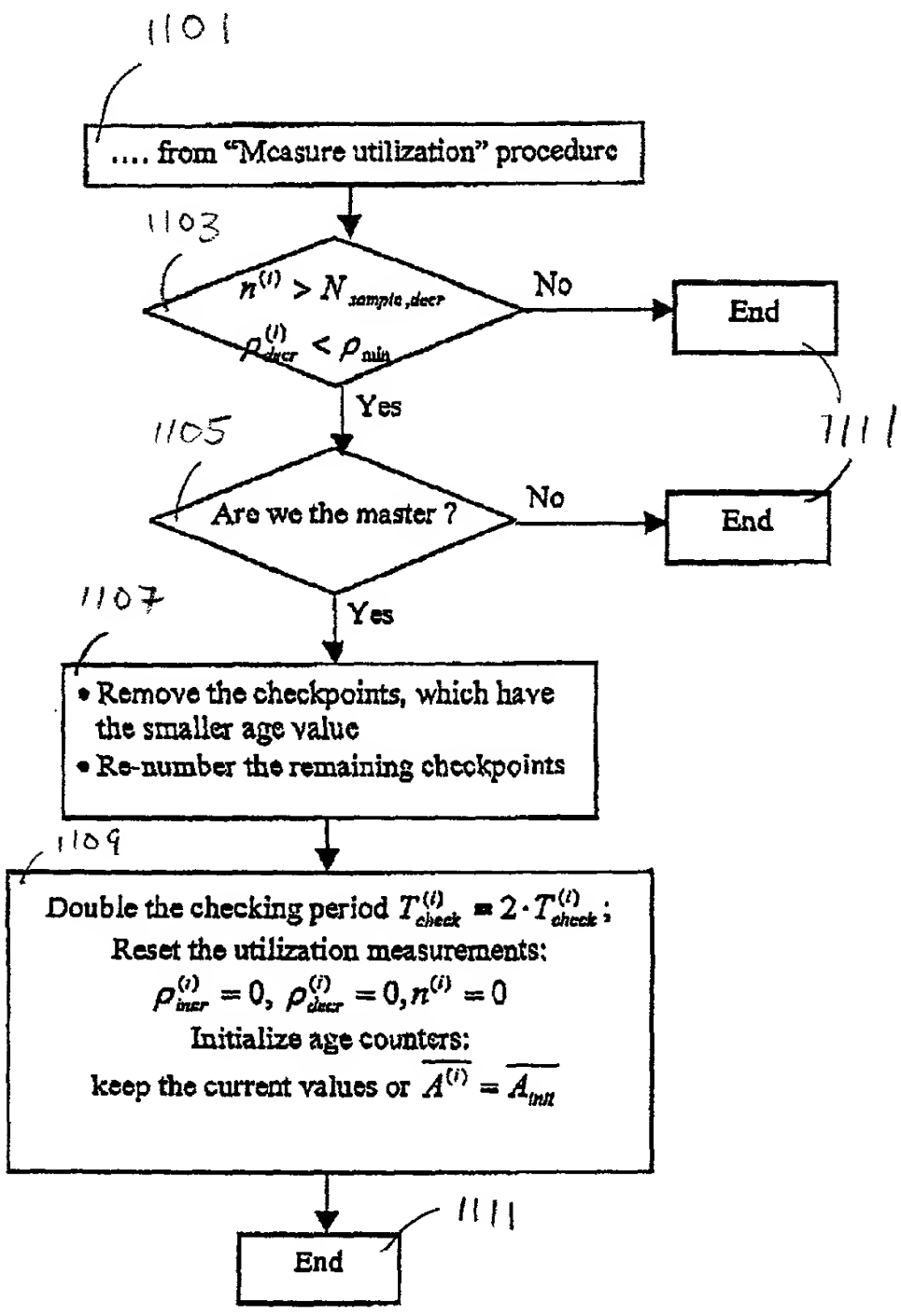

1101
.... from "Measure utilization" procedure
1103
$n^{(i)} > N_{sample,decr}$
$\rho_{decr}^{(i)} < \rho_{min}$
No
End
1111
Yes
1105
Are we the master ?
No
End
1111
Yes
1107
• Remove the checkpoints, which have the smaller age value
• Re-number the remaining checkpoints
1109
Double the checking period $T_{check}^{(i)} = 2 \cdot T_{check}^{(i)}$;
Reset the utilization measurements:
$\rho_{incr}^{(i)} = 0,\ \rho_{decr}^{(i)} = 0, n^{(i)} = 0$
Initialize age counters:
keep the current values or $\overline{A^{(i)}} = \overline{A_{init}}$
End
1111

FIG. 11

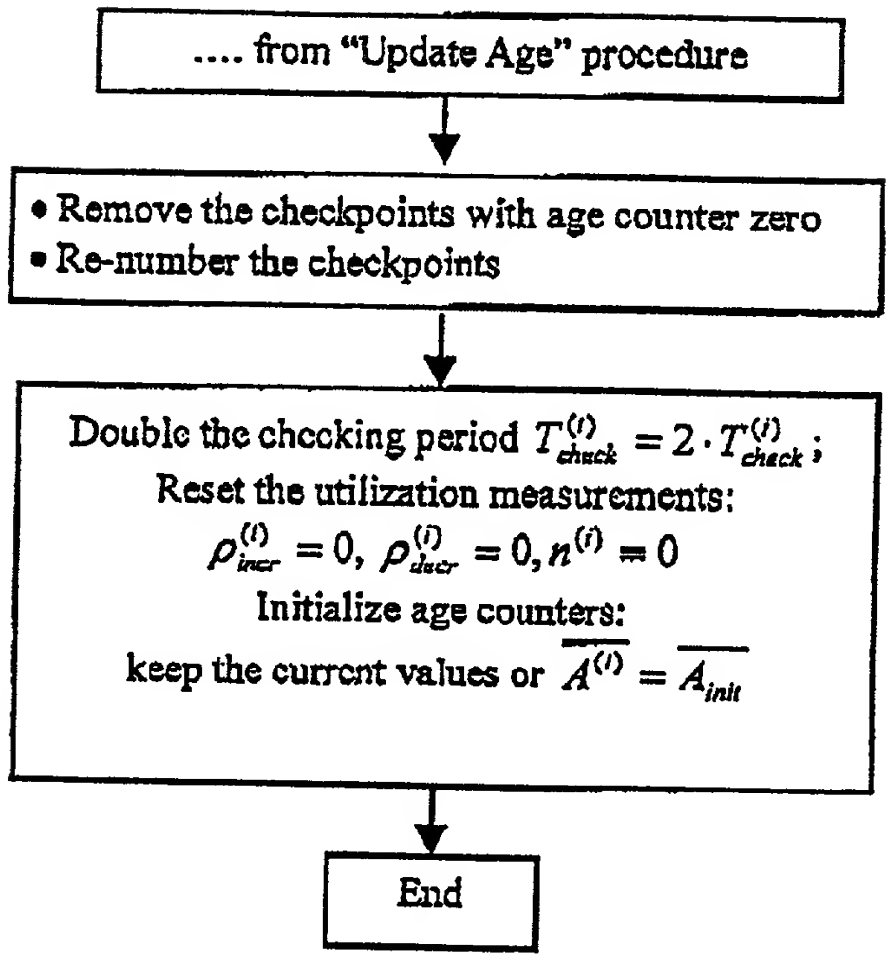

.... from "Update Age" procedure
• Remove the checkpoints with age counter zero
• Re-number the checkpoints
Double the checking period $T_{check}^{(i)} = 2 \cdot T_{check}^{(i)}$;
Reset the utilization measurements:
$\rho_{incr}^{(i)} = 0,\ \rho_{decr}^{(i)} = 0, n^{(i)} = 0$
Initialize age counters:
keep the current values or $\overline{A^{(i)}} = \overline{A_{init}}$
End

FIG. 12

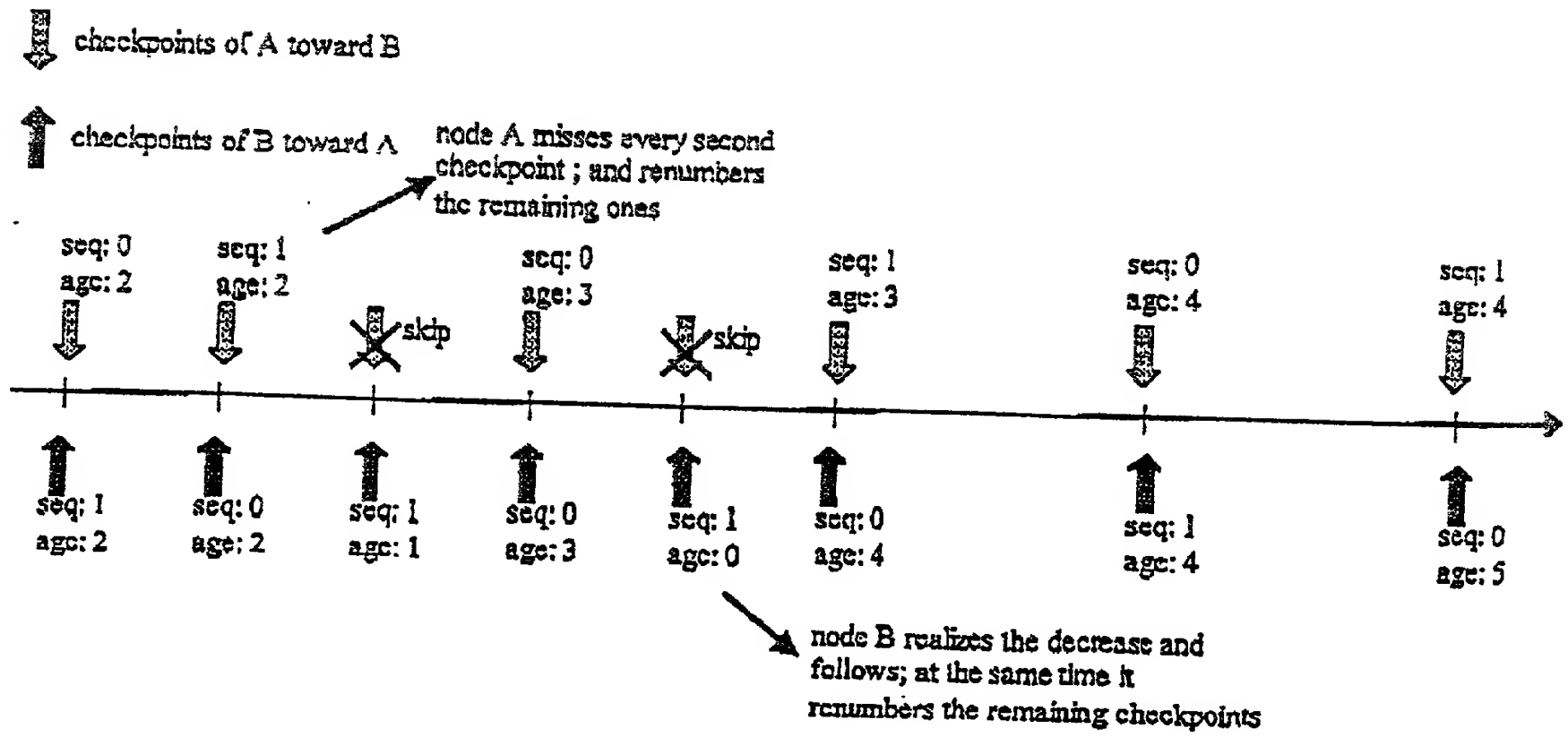


FIG. 13(a)

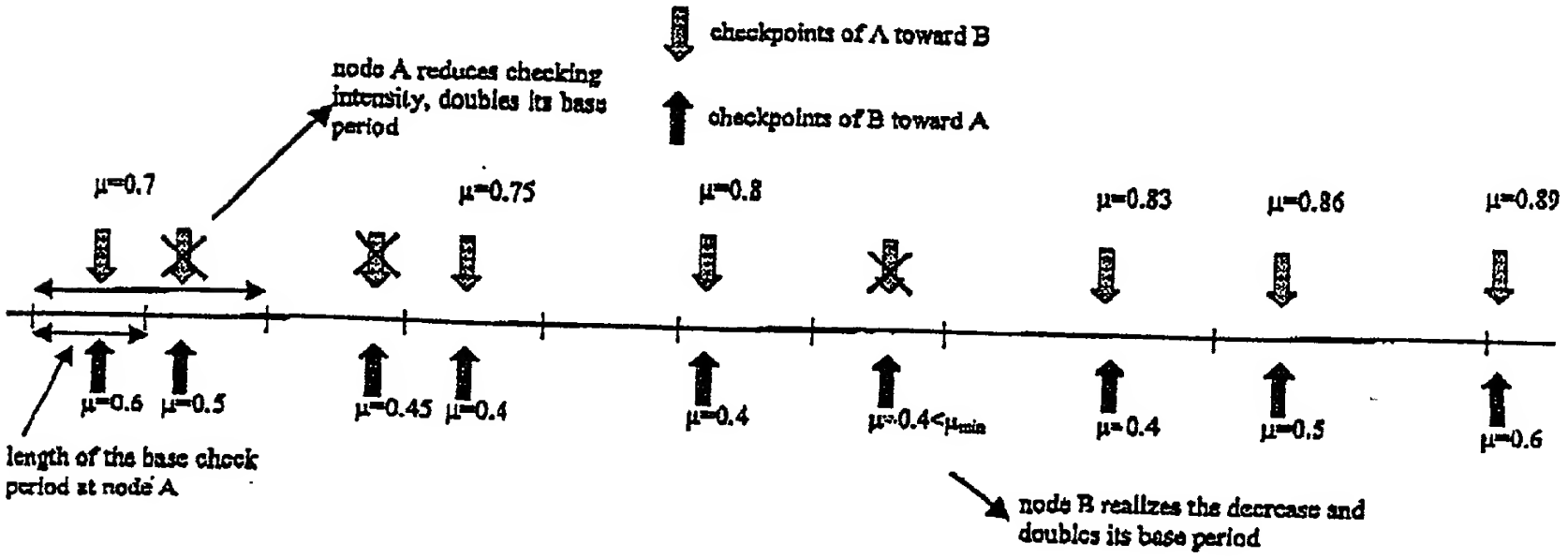


FIG. 13(b)

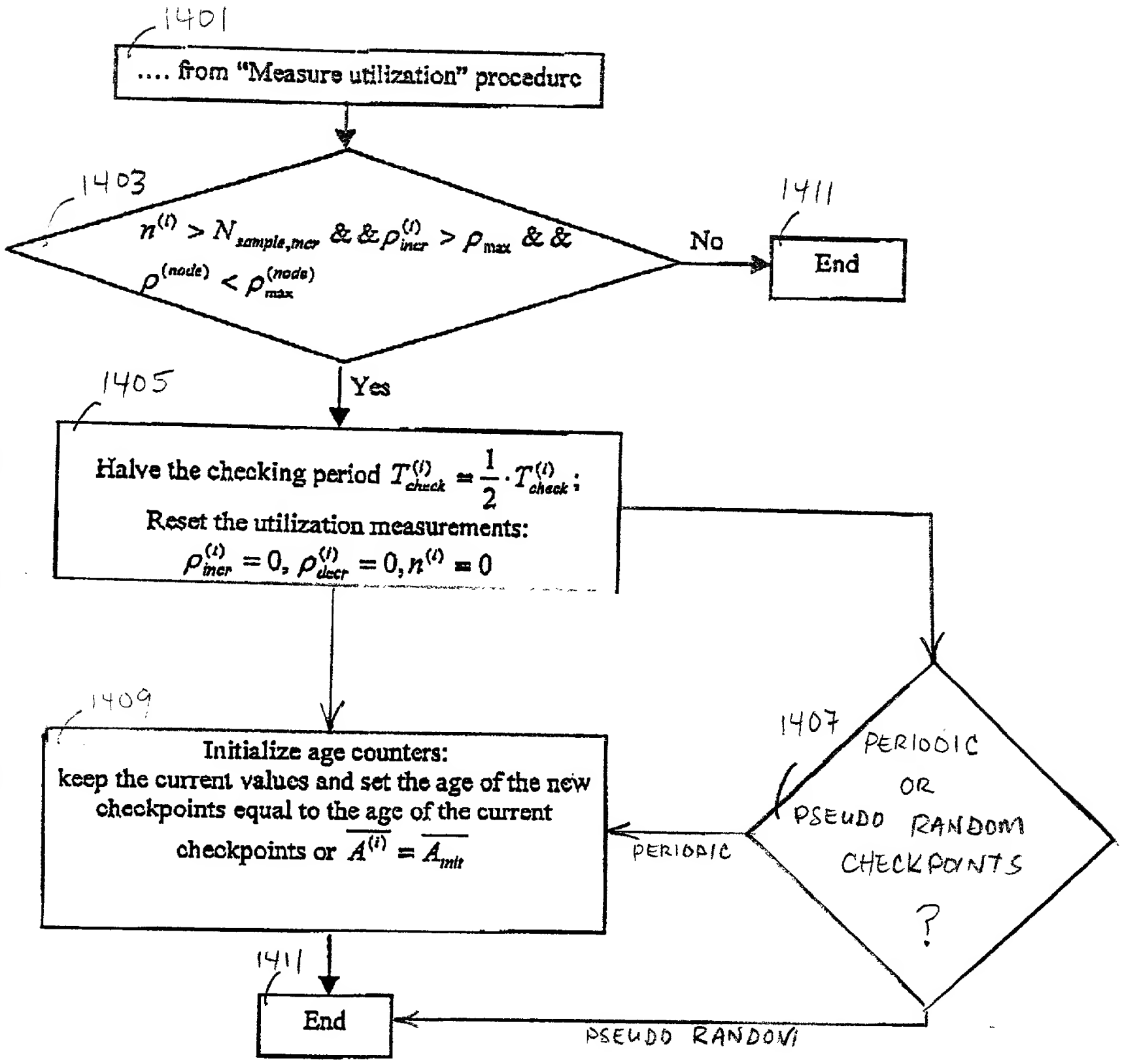

1401
.... from "Measure utilization" procedure
1403
$n^{(i)} > N_{sample,incr}$ && $\rho_{incr}^{(i)} > \rho_{max}$ && $\rho^{(node)} < \rho_{max}^{(node)}$
No
1411
End
Yes
1405
Halve the checking period $T_{check}^{(i)} = \frac{1}{2} \cdot T_{check}^{(i)}$;
Reset the utilization measurements:
$\rho_{incr}^{(i)} = 0, \rho_{decr}^{(i)} = 0, n^{(i)} = 0$
1407
PERIODIC OR PSEUDO RANDOM CHECKPOINTS ?
PERIODIC
1409
Initialize age counters:
keep the current values and set the age of the new checkpoints equal to the age of the current checkpoints or $\overline{A^{(i)}} = \overline{A_{init}}$
1411
End
PSEUDO RANDOM

FIG. 14

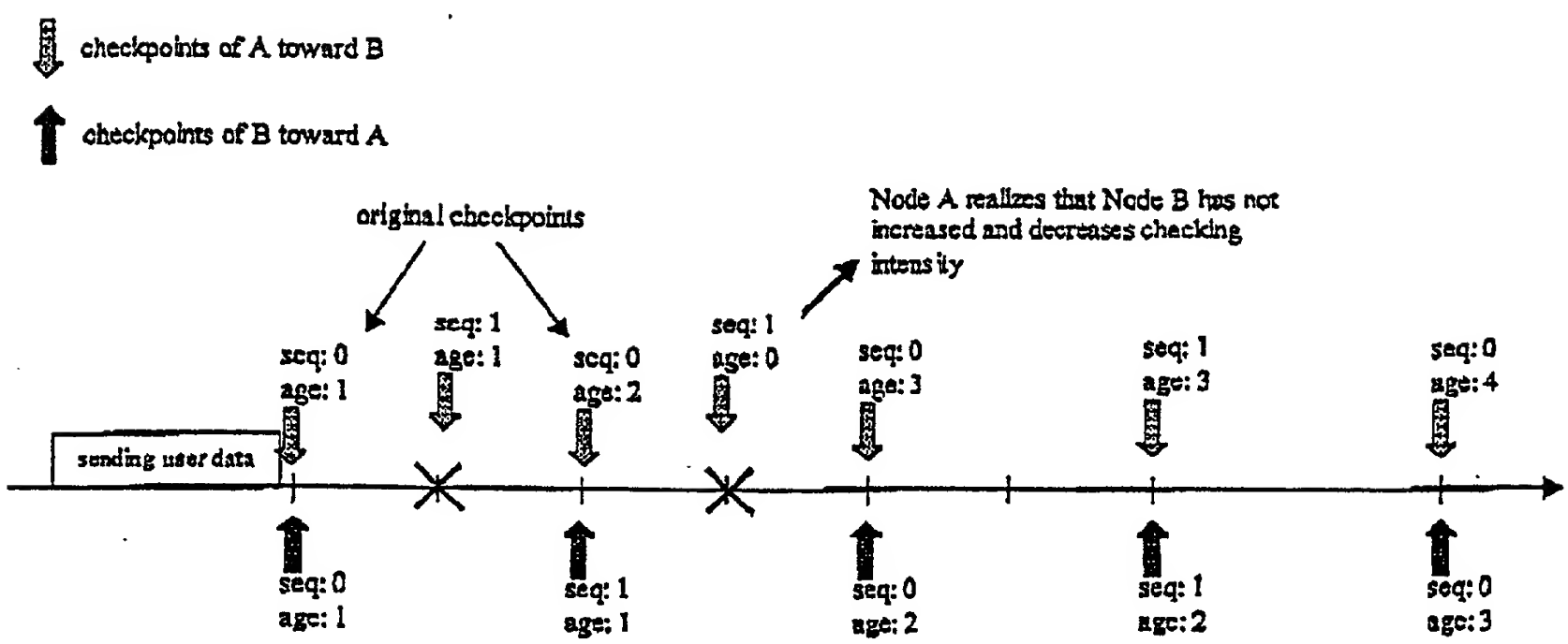

checkpoints of A toward B
checkpoints of B toward A
original checkpoints
Node A realizes that Node B has not increased and decreases checking intensity
sending user data
seq: 0 age: 1
seq: 1 age: 1
seq: 0 age: 2
seq: 1 age: 0
seq: 0 age: 3
seq: 1 age: 3
seq: 0 age: 4
seq: 0 age: 1
seq: 1 age: 1
seq: 0 age: 2
seq: 1 age: 2
seq: 0 age: 3

FIG. 15

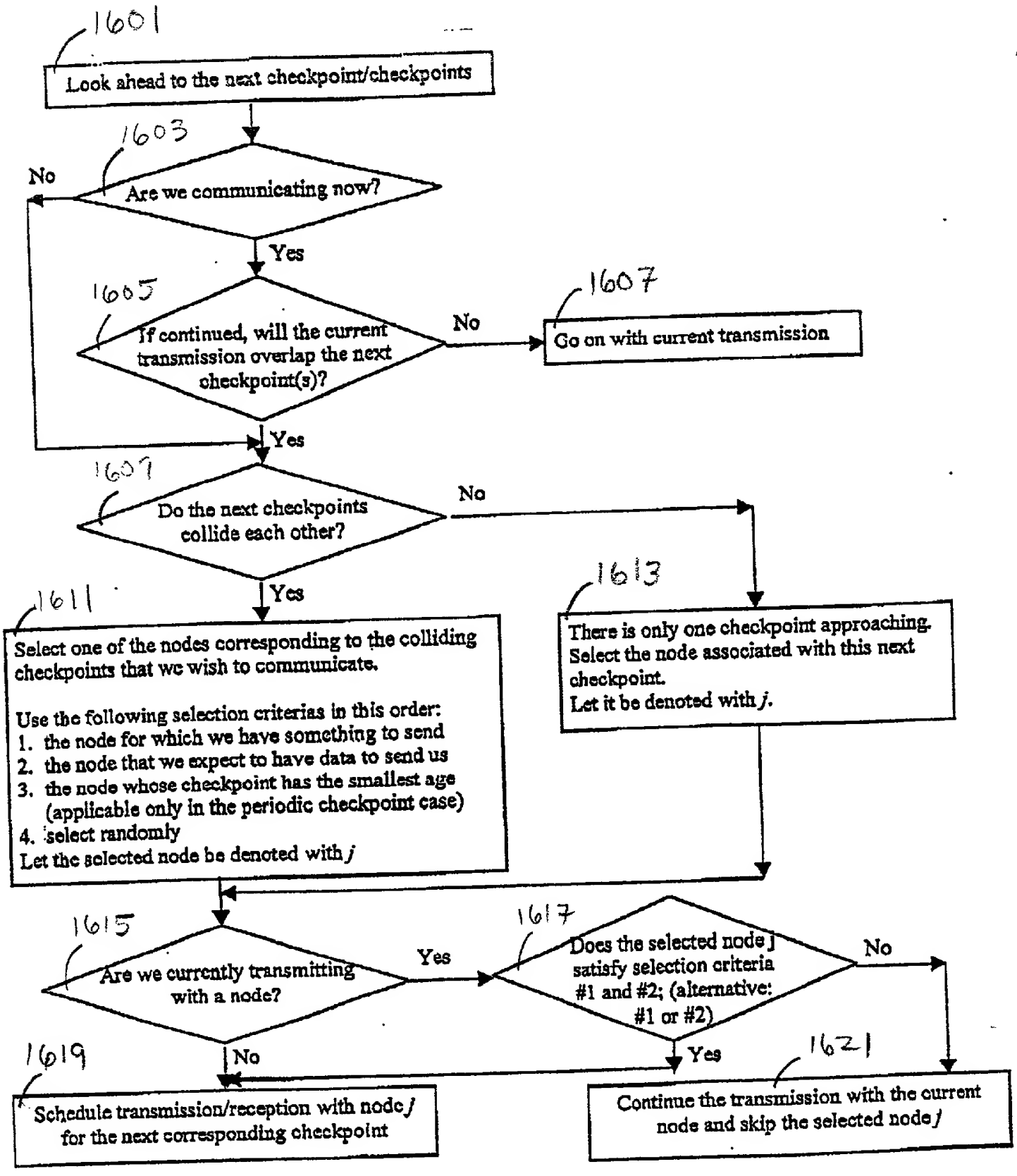

1601
Look ahead to the next checkpoint/checkpoints
1603
Are we communicating now?
No
Yes
1605
If continued, will the current transmission overlap the next checkpoint(s)?
No
1607
Go on with current transmission
Yes
1609
Do the next checkpoints collide each other?
No
Yes
1611
Select one of the nodes corresponding to the colliding checkpoints that we wish to communicate.
Use the following selection criterias in this order:
1. the node for which we have something to send
2. the node that we expect to have data to send us
3. the node whose checkpoint has the smallest age (applicable only in the periodic checkpoint case)
4. select randomly
Let the selected node be denoted with j
1613
There is only one checkpoint approaching. Select the node associated with this next checkpoint.
Let it be denoted with j.
1615
Are we currently transmitting with a node?
Yes
1617
Does the selected node j satisfy selection criteria #1 and #2; (alternative: #1 or #2)
No
Yes
1619
No
Schedule transmission/reception with node j for the next corresponding checkpoint
1621
Continue the transmission with the current node and skip the selected node j

FIG. 16

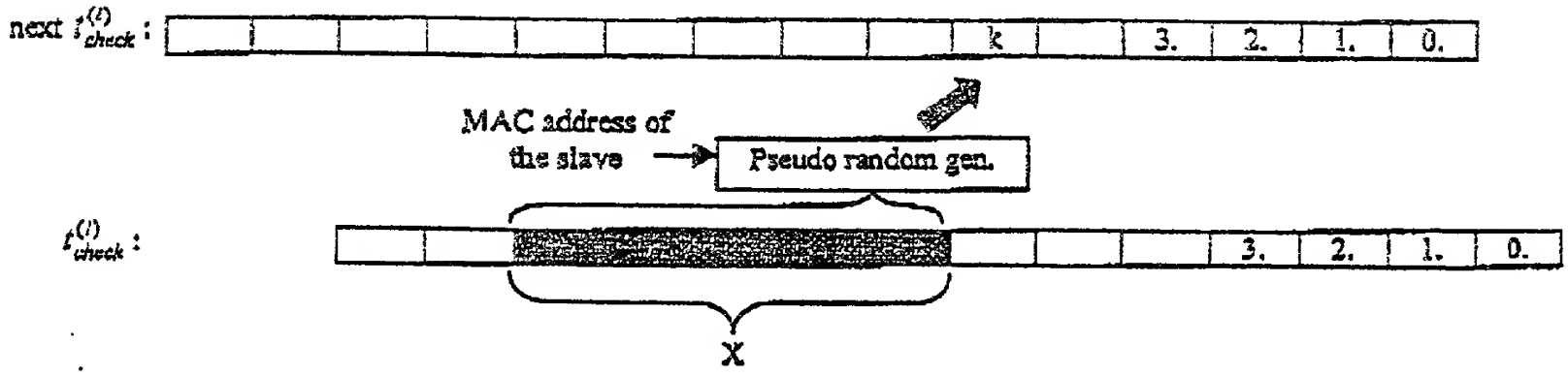


FIG. 17

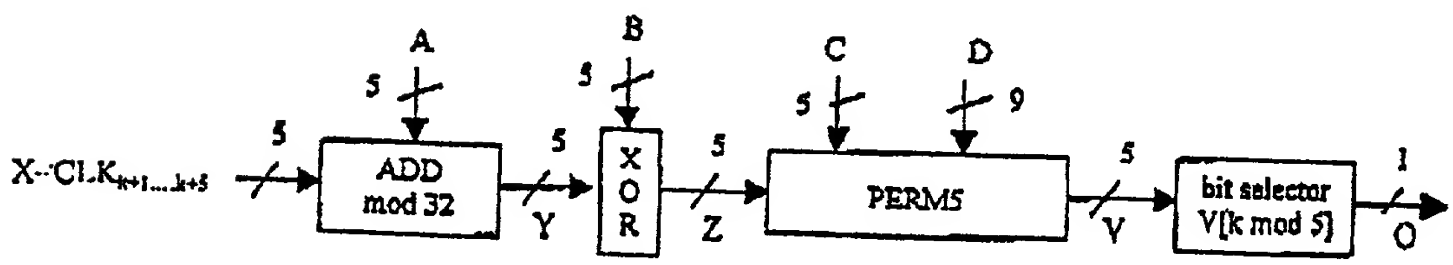


FIG. 18

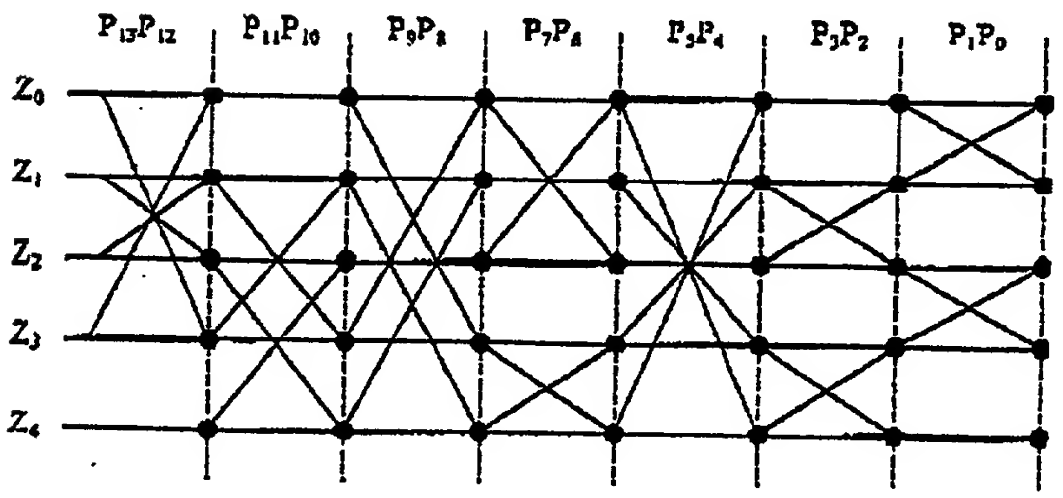


FIG. 20

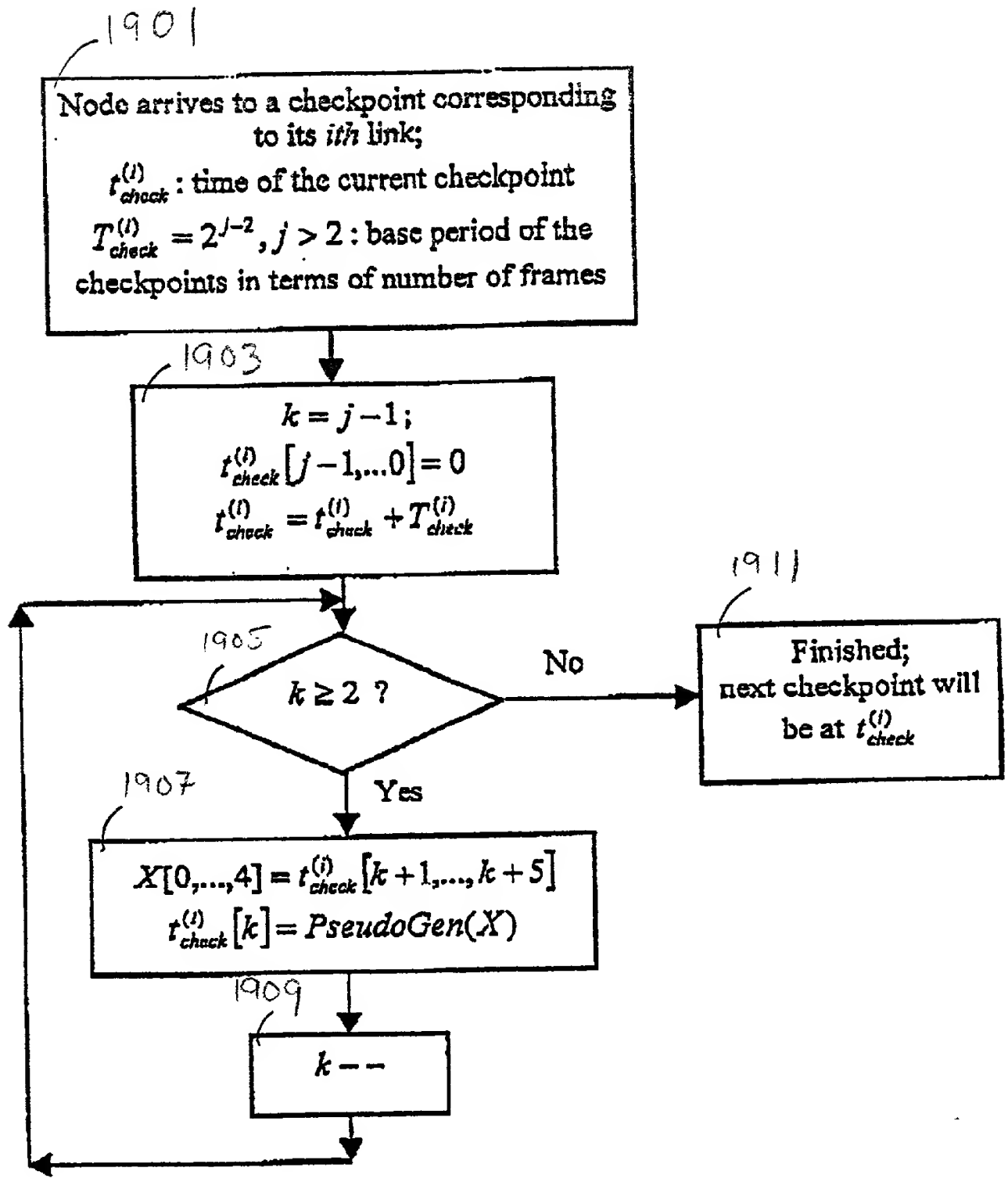

1901
Node arrives to a checkpoint corresponding to its ith link;
$t^{(i)}_{check}$: time of the current checkpoint
$T^{(i)}_{check} = 2^{j-2}, j > 2$: base period of the checkpoints in terms of number of frames
1903
$k = j - 1;$
$t^{(i)}_{check}[j-1,...0] = 0$
$t^{(i)}_{check} = t^{(i)}_{check} + T^{(i)}_{check}$
1905
$k \geq 2$?
No
1911
Finished; next checkpoint will be at $t^{(i)}_{check}$
Yes
1907
$X[0,...,4] = t^{(i)}_{check}[k+1,...,k+5]$
$t^{(i)}_{check}[k] = PseudoGen(X)$
1909
$k--$

FIG. 19

Node architecture:

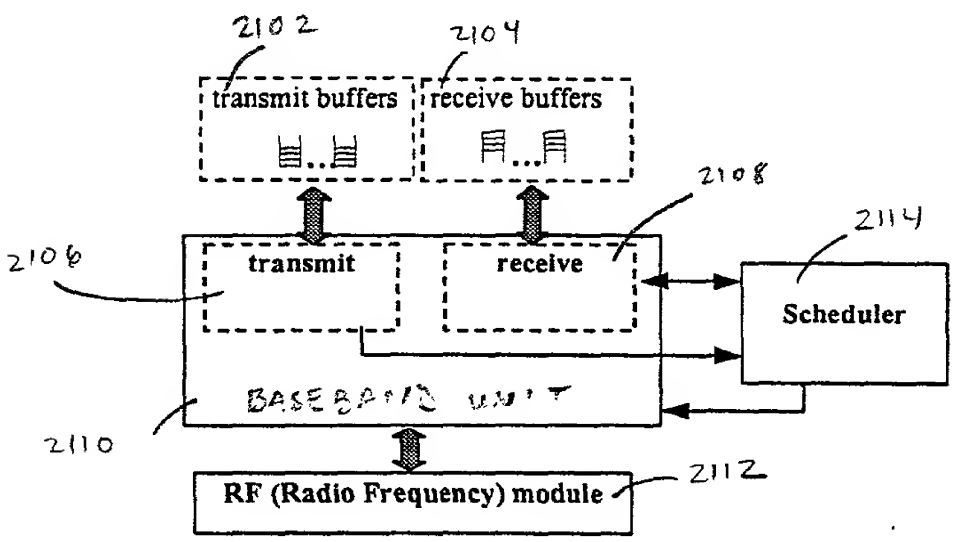


FIG. 21(a)

Architecture of the scheduler:

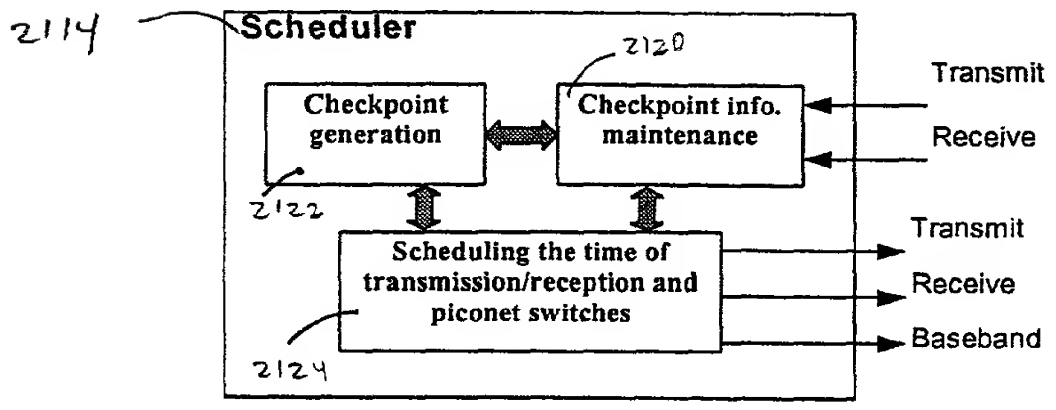


FIG. 21(b)